AD-A285 803

APPROVED FOR PUBLIC RELEASE
DISTRIBUTION UNLIMITED

REPORT NO. 94-R-06
PROJECT NO. 93-P-120

Caroline J. Buckey
Mechanical Engineer
Defense Switching Network 787-4519
Commercial (513) 257-4519

Defense Ammunition Packaging Council Project J3

Development of Improved Anti-static Cushioning Materials for Ammunition Containers

HQ AFMC/LGTP
Air Force Packaging Evaluation Activity
Wright-Patterson AFB OH 45433-5999

September 1994

NOTICE

PROJECT: 94-P-120

TITLE: DAPC J3 -- Development of Improved Anti-Static Cushioning Materials for Ammunition Containers

ABSTRACT

See Executive Summary

For	
	X
By	
Distribution /	
Availability Codes	
Dist	Avail and/or Special
A-1	

PREPARED BY:

Caroline J. Buckey

CAROLINE J. BUCKEY
Mechanical Engineer
AF Packaging Eval. Activity

PUBLICATION DATE:

30 SEP 1994

REVIEWED BY:

L A Wood

LARRY A. WOOD
Supervisor, Materials Engrg.
AF Packaging Eval. Activity

APPROVED BY:

Leslie K Clarke III

LESLIE K. CLARKE, III
Chief, AF Packaging
Evaluation Activity

Executive Summary

This report will cover DAPC Project J3, "Development of Improved Anti-static Cushioning Materials and Dynamic Performance Testing for Ammunition Containers" for fiscal year 1994. This is a joint-service project managed by the Air Force Packaging Evaluation Activity, Wright-Patterson AFB, OH, and coordinated with the US Army, Packaging Division, Picatinny Arsenal, NJ, the Packaging, Handling, Storage and Transportability Center at Naval Weapons Station Earle, NJ, and the US Marine Corps, Naval Surface Warfare Center, Crane, IN.

The original intent of this project was to research only anti-static cushioning materials for use in ammunition containers and to develop dynamic tests along with a performance database for use in cushion design. In the past few years, foam cushioning suppliers have been producing non-ozone depleting cushioning with flammable blowing agents which could cause an explosion when shipping, storing, or handling a sealed container. This project was expanded to include non-ozone depleting and non-flammable blowing agents to protect the environment along with making it safe to ship, store, and handle the sealed ammunition containers.

This year's research of cushioning materials included development of cushion curves on anti-static and non-ozone depleting cushioning materials, and non-flammable blowing agents used to produce cushioning materials. Container designers will use the cushion curves to determine the cost, type, and amount of cushioning needed in the containers to protect the item. Other properties of the cushions were also tested and studied to determine which materials are the most suitable. These studies included non-flammable blowing agents, shortened dynamic cushion testing studies, compressive creep study, cold temperature performance tests, and finite element analysis and cushioning. A user-friendly cushion design computer program was developed. This program will improve and expedite the container design process.

The benefits of this project are numerous. The most important benefit of this project is the promotion of the use of anti-static cushioning materials and non-ozone depleting materials which are safe for shipment, storage, and handling of ammunition. Because this project is a joint-service project, the results of this project will benefit all services. This project improves container design and facilitates procurement of quality materials by giving the design engineer better materials and information about the specifics of those materials.

Future efforts on this project focus on giving the design engineer the knowledge and tools required to use the anti-static, non-ozone depleting and safe materials. They include cold-temperature performance testing, distribution of the cushion design program, further research on non-flammable blowing agents, shortened cushion curve testing, and finite element analysis and cushioning.

TABLE OF CONTENTS

1.0 Introduction

1.1 Scope. The Army, under direction of Congress, formed the Defense Ammunition Packaging Council (DAPC) to investigate ammunition packaging requirements and perform basic research and development in an effort to solve problems identified for ammunition. PM-AMMOLOG, Picatinny Arsensal, NJ is managing the overall program for Congress. All DOD services are participating.

DAPC consists of many projects. The project that this paper will cover is DAPC Project J3, "Development of Improved Anti-static Cushioning Materials and Dynamic Performance Testing for Ammunition Containers." This is a joint-service project managed by the Air Force Packaging Evaluation Activity, Wright-Patterson AFB, OH, with participation from the US Army, Packaging Division, Picatinny Arsenal, NJ, the Packaging, Handling, Storage and Transportability Center at Naval Weapons Station Earle, NJ, and the US Marine Corps, Naval Surface Warfare Center, Crane, IN.

The original intent of this project was to research only anti-static cushioning materials for use in ammunition containers and to develop dynamic tests along with a performance database for use in cushion design. The project expanded into cushioning that also does not contain ozone-depleting and flammable substances. In the past few years, foam cushioning suppliers have been producing non-ozone depleting cushioning with flammable blowing agents which could cause an explosion when shipping, storing, or handling a container. This project was expanded to include non-ozone depleting and non-flammable blowing agents to protect the environment along with making it safe to ship, store, or handle the ammunition containers.

The research of cushioning materials includes development of cushion curves on anti-static and non-ozone depleting cushioning materials, and non-flammable blowing agent used to produce cushioning materials. Container designers will use the cushion curves to determine the type and amount of cushioning needed in the containers to protect the item. Other engineering properties of the cushions will also be tested and studied to determine which materials are the most suitable. These studies include isobutane studies, shortened dynamic cushion testing studies, compressive creep study, extreme temperature performance tests, and finite element analysis and cushioning. A cushion design computer program will also be produced.

The development of dynamic tests and a performance database will include improvements to the cushion drop test and how to make the test match the performance of the container during a drop test more closely. This topic is not covered in this paper because dynamic performance testing will be accomplished in future fiscal years, if funding is available.

1.2 Overall Benefits. The benefits of this project are numerous. Because this is a joint service project, the results of this project will benefit all services.

There will be standardization of cushioning materials which will improve the safety of the ammunition containers with subsequent benefits to non-ammunition containers as well.

This project improves container design and facilitates procurement of quality materials by giving the design engineer better materials and information about the specifics of those materials.

This project promotes the use of not only anti-static cushioning materials, but also the use of non-ozone depleting materials which are safe for shipment and storage of ammunition.

This project promotes metric use and conversion because most of the results are in metric units.

1.3 Schedule The overall project schedule is included in Appendix A. It depicts the work that has been accomplished as of September 1994. The schedule is split into different sub-projects which include

Cushion Curve Testing, Updating of the Cushion Design Program, and Generation of the Final Report. See 2.0 Work Accomplished for specific explanations in each of these areas.

1.4 Funding. The FY 94 funding for the total program was $168,000.00. Contract Funding consisted of two directly funded projects. One the Cushion Curve Testing Contract for $97,500.00 and the other was the Cushion Design Program for $20,000.00. The remaining funds covered in-house and other government expenses.

Funding (K$)	FY94	FY95	FY96
Total	168	200	145
In House	20.5	20	15
Other Gov.	30	30	30
Contract	117.5	150	100

1.5 Future Efforts. Future efforts on this project focus on giving the design engineer the knowledge and tools required to use the anti-static, non-ozone depleting and safe materials. They include cold temperature performance testing, distribution of the cushion design program, further research on non-flammable blowing agents, shortened cushion curve testing, and finite element analysis and cushioning.

Overall DAPC J3 POC: Ms. Caroline J. Buckey
(See Appendix B for Listing and Addresses of POCs)

2.0 Work Accomplished.

2.1 Cushion Curve Testing Contract.

2.1.1 Scope. The Cushion Curve Testing Contract is the largest single portion of the project, consisting of $97,500.00. The purpose of the contract is to develop peak acceleration/static stress curves for 10 new materials. The curves will be used by container designers in development of containers with anti-static, safe, and non-ozone depleting foam cushioning materials.

2.1.2 Specific Benefits. Benefits include the development of cushion design curves on new materials with the following desired properties: anti-static, non-ozone depleting, and non-isobutane. The data and curves generated will help container designers by providing much-needed data on the materials with the above properties. Furthermore, the data from this research can be used as a baseline for future fiscal year studies.

2.1.3 Test Procedures. The contractor will develop curves for ten materials and two manufacturers per material for a total of 400 curves. The contractor will use a dynamic cushion testing machine which drops a specific weight on a cushion and the peak acceleration is recorded on a data acquisition system. The contractor will follow the test procedures listed in the statement of work provided in the contract.

2.1.4 Results. The contract was awarded to Lansmont Corporation, Lansing, MI. The contract was awarded on 28 Jun 94 for $97,500.00.

The contractor is ordering materials and setting up for testing. Testing should start in October and the first of ten interim test reports is expected in November. At that point, the contractor would have completed the first of ten materials. The contractor has one year to complete testing, according to the contract, and is required to complete their reports by the end of June 1995.

The contractor will provide the data generated from these curves. The data will be in following forms: the test report form specified in the data item description, the curves drawn on graphs, and the raw data on computer diskettes.

2.1.5 Future Efforts. Future efforts in this area depend on the availability of funds for the next year. Container design engineers have expressed an interest in cold testing data for cushion curves. AFPEA has started research on what test procedures and equipment are needed to conduct this type of testing. If funding is approved and allocated, many materials can be tested and much needed cold-testing data could be generated for use by packaging designers.

Any lessons learned from the current contract will be incorporated into future year contracts.

The data from this research can be used as a baseline for future studies including the Dynamic Performance Testing (1.1) and Shortened Cushion Curve Testing (2.3.2).

POC: Ms. Caroline J. Buckey (See Appendix B)

2.2 Cushion Design Computer Program Update.

2.2.1 Scope. The current AFPEA Cushion Design Computer Program generates design information peak acceleration for an existing cushion pack and assists in the design for complete cushioning encapsulation of an item, corner-pad cushioning design and cushion wrap design of an item. Each of the options consider drop heights, dimensions, weight, fragility container type, container materials, cost and mode of transportation. Costs and output results are either displayed to the screen or to both the screen and printer. An option is provided to make changes to the current input data and then rerun the analysis.

2.2.2 Specific Benefits. The new Cushion Design Program provides many benefits over the existing version. The updated version of the program will be Windows compatible and will be more user-friendly. The container designer will be able to see the graph of the curve and the area of concern. Also the program will have on-line help and the ability to use a mouse. Because the program is in Windows, the user will be able to "click" on the various characteristics they want and then save them to a file for later use. An important benefit is the ease of adding new information. For example, the new cushion curves from the Cushion Curve Contract (2.1) can be added with very little effort.

This contract is the modification of the AFPEA 304 Cushioning Design Program Software to perform the following functions:
-- Display data in peak acceleration versus static stress on a semi-log x-y plot for use in selection of material
-- Output a peak acceleration versus static stress plot displaying a lined or shaded area where the selection lies.
-- Have the ability to save information to a file for later retrieval and/or modification.
-- Option to easily revise data files and input updated data including more cushioning materials and prices.
-- On-line help instructions
-- Keep the data in a user-friendly database.
-- Ability to use mouse or arrow keys.
-- Opening instructions and any documentation to support the new version.

2.2.3 Results. The contract cost is $20,000.00. The contractor started work in February. The rough draft will be ready September 1994. The rough draft will be coordinated with all services. The final product is expected prior to close of calendar year 1994.

2.2.4 Distribution and Future Efforts. Initially, distribution of the program will be done on diskettes and sent to previous customers and DAPC members. When the Tri-Service Packaging "Information Center" on the World Wide Web is fully functional (DAPC Project J1), then this program may be linked to the Information Center and anyone who has privileges to the system can access the Cushioning Design Program.

The cushion design curves generated from the Cushion Curve Testing Contract (2.1) can be used to update the program giving the design engineer the most recent data.

POC: Ms. Susan J. Misra (See Appendix B)

2.3 Other Studies. In addition to the studies listed previously, AFPEA and other Department of Defense agencies have been performing in-house studies on cushioning. Most of these topics have emerged within the last year. The studies are at various stages of completion. See each specific topic for status and future efforts.

2.3.1 Non-flammable Blowing Agent Studies.

2.3.1.1 Scope. The Air Force Packaging Evaluation Activity (AFPEA), HQ AFMC/LGTP has been investigating Polyethylene (PE) Cushioning Material in sealed shipping containers since October 1993. A container exploded Oct 93 due to alleged improper welding practices at Thiokol in UT, alerting packaging people to a potential hazard. As the packaging industry now knows, the replacement of ozone depleting Freon blowing agents resulted in industry use of three flammable gases as blowing agents in the process of producing Military Specification Polyethylene (PPP-C-1752). These gases can remain inside sealed containers for extended time periods, perhaps the life of the container depending on how often it is opened and allowed to ventilate. No incident has occurred to date in packaging, storage, or transportation of these products.

2.3.1.2 Results. AFPEA has hosted joint DOD meetings to coordinate both long and short term solutions to this potential problem. The result of these meetings has been the formation of joint DOD engineering and policy teams to analyze various aspects of the concern. The following actions have been taken by the Air Force:

a. Container design engineers have decided to ban the use in new container designs of flammable blowing agents used in producing cushioning.

b. AFPEA has taken the lead in identifying non-flammable substitute materials for use in new designs and for the possible retrofit of fielded containers during the normal refit schedule. Also in work is an amendment to PPP-C-1752 to prohibit the purchase of the flammable materials.

c. AGMC/MAEL (Newark AFB) has tested and analyzed the possibility of static electricity (ESD) as an ignition source. The resulting report recommendations were incorporated into AF Safety messages.

d. Coordinated LG/XR/SE Safety messages have been issued to field activities alerting them to possible dangers when opening containers. The messages contain ventilation and grounding recommendations that, if followed, eliminate any known danger to personnel or equipment.

e. Container searches have been undertaken to identify the magnitude of the problem. To date, over 45,000 containers are fielded that may contain some level of the flammable gas. Because of multiple contracts to sub-contractors and an extensive list of government and industry container refurbishment activities, we have been unable to define an exact list.

f. A joint Air Force Material Command LG/XR/SE field study was completed. The intention was to identify containers that pose a potential risk. Results are that fielded containers exist with gas levels

above LEL. Joint LG/XR/SE meeting concluded that current Air Force safety procedures are sufficient to control these conditions.

2.3.1.3 Future Efforts. GSA will process the PPP-C-1752 amendment to prohibit government purchase of the offending material. The DOD will continue joint meetings as needed to assess the risk and progress made on this condition.

Overall Isobutane POC: Mr. Larry A. Wood (See Appendix B)

2.3.1.3 Listing of Studies.

2.3.1.3.1 Electrostatic Discharge (ESD) Assessment of Polyethylene Foam (Report)

Summary: The Air Force ESD Control Technology Center at Newark AFB, conducted tests on both an aluminum container and foam as part of the "ESD Team" established at the 16-17 Nov 93 meeting at AFPEA. ESD entered into discussions as a potential ignition source of flammable blowing agents.

The object of this study was to determine the possibility of ignition of an isobutane-oxidant concentration within a missile shipping container with ESD as the ignition source. Focus was placed on the routine handling and the opening of those containers having potentially hazardous levels of isobutane and discharge energies that could be attained in this process.

Testing verified that although electrostatic potentials could be generated on the cover and/or base and personnel associated with opening missile shipping containers, the probability of this event causing ignition was highly improbable. The report recommended an interim solution of grounding the container when opening a container with foam containing high levels of isobutane. The long term solution is to procure foam with ESD-safe properties and non-flammable blowing agents (2.3.1).

Date of Study: 20 Dec 93
POC: Mr. Steven C. Gerken (See Appendix B)

2.3.1.3.2 Use of Adsorbent to Remove Blowing Agent from Closed Container (Letter)

Summary: The objective of this letter report was to determine whether the use of adsorbent to remove blowing agent from the vapor phase is a feasible solution to the problem of using flammable blowing agents for foams in closed containers. Calculations were done to show how fast the blowing agent would be adsorbed. The appropriate amount of adsorbent was calculated for two different container and foam combinations to remove the blowing agent. Many assumptions were used. The writer suggested that these calculations be backed up with tests on actual containers.

Date of Study: 12 Jan 94
POC: Ms. Ruth M. Doherty (See Appendix B)

2.3.1.3.3 Potential Replacement Cushioning Materials which meet Requirements for PPP-C-1752, Polyethylene Foam (Letter)

Summary: In order to identify replacement materials for flammable blowing agent polyethylene foams, AFPEA performed dynamic cushion testing in accordance with PPP-C-1752D on almost twenty materials. AFPEA identified substitutes for Type I, Class 2 and Types III, IV & V polyethylene foams. See POC below for specific replacements. The writer notes that the testing was accomplished on one thickness of material at one drop height. Each material may have a different set of design curves and other associated material properties. It will be the responsibility of each organization to determine which material properties are the most important for its own needs and design/redesign packaging accordingly.

Date of Study: 3 Mar 94
POC: Ms. Susan J. Evans (See Appendix B)

2.3.1.3.5 LGTP Report 94-R-02, Container Venting of Isobutane Blowing Agent in Transport Aircraft

Summary: In a sealed container, the released blowing agent accumulates and is released into its external environment as the container vents. The question of a combustible gas concentration both internal and external to the container arises. For an aircraft transporting such containers, excessive venting into the external environment may occur either from container temperature changes, while the aircraft is on the ground, or from changes in cabin pressure, resulting from aircraft ascent and environmental controls.

Calculations were done for both cases. The first case involved a closed aircraft which was stationary on the runway and was exposed to solar input without the ventilation system operating and with maximum container load. The conditions of the example included a 40°F temperature rise from 80°F to 120°F, and concentration of each container at 100% LEL. The maximum isobutane concentration was 5.17% LEL.

The second case involved an aircraft climbing at 2000 feet per minute with the ventilation system regulating cargo compartment pressure to correspond to altitude, but limiting the pressure to that of 8000 feet. The maximum cargo compartment gas concentration occurs at the time the aircraft attains the altitude of 8000 feet. The conditions of the example included a temperature of 80°F, and concentration of each container at 100% LEL. The maximum isobutane concentration was 6.2% LEL.

Both concentrations were at very low levels of isobutane concentration, meaning loading an aircraft to the maximum extent possible with 100% LEL concentration of containers would not cause an explosive situation in the aircraft.

Date of Study: 11 Mar 94
POC: Mr. Edward P. Moravec (See Appendix B)

2.3.1.3.4 Container Foam Pilot Test Report.

Summary: This study examined the combustible gas levels in a sample of containers. The test results showed that none of the measured containers reached the Lower Explosive Limit (LEL) of isobutane, HCFC 142b, or HFC 152A. The test engineer noted the importance of the 20 day diffusion period, in which the container is sealed, to allow for equilibrium to establish throughout the container. The engineer also noted that the LEL gas levels were independent from the container year. For example, the newer containers were expected to have higher LELs. This was not the case in this study.

Date of Study: 17 Mar 94
POC: Lt. Darrel Thomas (See Appendix B)

2.3.1.3.5 LGTP Report 94-R-03, Container Venting of Isobutane Blowing Agent in Transport Truck

Summary: In a sealed container, the released blowing agent accumulates and is released into its external environment as the container vents. The question of a combustible gas concentration both internal and external to the container arises. For a truck transporting such containers, venting into the external environment may occur either from elevation changes or changes in container temperature and barometric pressure.

The study considered filling 40-foot semitrailers with 2090 cubic feet with 12 containers (182" x 35" x 25") containing 100% LEL. Four different situations were calculated. The first example considered a

stationary unventilated semitrailer and a temperature change from 40°F to 120°F results in a maximum isobutane concentration of 2.25% LEL. The second example considered an unventilated semitrailer at -20°F driven into a 70°F warehouse. The maximum isobutane concentration was 9.6% LEL. The third example considered an insulated, unventilated semitrailer at 68°F going from sea level (14.7 psi) to 10666 feet (9.82 psi). The isobutane concentration in the trailer will rise to a maximum value of 25.1% LEL. The fourth example considered a insulated, ventilated semitrailer with the same conditions as example three. Ventilation consisted of only a 1-inch diameter hole in the truck's front and rear ends. With this small amount of ventilation, the isobutane concentration went down to 2.28% LEL.

Contrasting examples 3 and 4 showed only modest ventilation is needed to decrease the isobutane concentrations to lower levels of isobutane concentration. Lack of truck air tightness in most trucks would significantly reduce isobutane concentrations.

Date of Study: 2 May 94
POC: Mr. Edward P. Moravec (See Appendix B)

2.3.1.3.6 Results of Experiments Conducted to Determine Isobutane Displacement in an Open Container

Summary: The purpose of this study was to evaluate the displacement of isobutane from a drum after the lid has been removed. The test was used as a simulation of opening an ammunition case which was filled with isobutane-blown foam packing material. The study concluded that isobutane does not remain in the drum at all after opening; rather, convection seems to remove isobutane in less than 60 seconds to the point where it cannot be detected.

Date of Study: 18 May 94
Industry POC: Mr. Rich Striebich
Government POCs: Ms. Ellen Stewart and Lt. John Garver
(See Appendix B)

2.3.2 Shortened Dynamic Cushion Testing Studies

2.3.2.1 Scope. This sub-project consists of two studies. Both studies concern shortening of dynamic cushion testing. The amount of time, labor, and materials needed to generate cushion design curves now is enormous. For one material in 2.1, there are 3000 drops required. These studies purport that many fewer drops are required to generate the same data. If these studies can be used reliably to generate design curves, tremendous savings in labor, time and materials would be realized.

2.3.2.2 Cushion Design Curve Prediction. This project is an extension of an idea resulting from a contract with Battelle Memorial Institute in 1979. "Development of Simplified Methods for Determining the Shock Mitigating Properties of Packaging Materials". In their final report, Batelle developed a set of force balance equations for use in predicting cushion design curves.

Mr. Dave Filsinger, HQ AFMC/LGTPM, has reopened the project to explore the use of high strain rate data obtained from standard cushion impact data. This data is obtained by using a single weight on the platen to impact material of various thicknesses and at various drop heights. The force/time curves generated after impact are used as input to the model to develop the complete set of design curves for various drop heights, cushion thicknesses, and static stresses.

A PC-based FORTRAN program has been written to test the feasibility of the method. Impact data for 2-pound density polyethylene and 1.3-pound polypropylene have been used to debug and test the program. At this time, the results of the tests are encouraging.

2.3.2.2.1 Future Efforts. Mr. Filsinger will continue to research this project in the next fiscal year. He will test his hypothesis on more materials and more thicknesses of materials and report his findings.

POC: Mr. David Filsinger (See Appendix B)

2.3.2.3 Consolidation of Cushion Curves. Dr. Gary Burgess, Professor at Michigan State University, has published a proposal for a simplified method for the consolidation of all the conventional cushion curves for a particular material into a single relationship. The method requires only one of the cushion curves for an arbitrary drop and cushion thickness to deduce the dynamic stress-strain curve for the material. The results may be used to generate all other cushion curves regardless of drop height, cushion thickness, or static loading.

2.3.2.3.1 Future Efforts. AFPEA has reviewed Dr. Burgess' work and the results look encouraging for the materials he has tested up to now. Further study needs to be done on more materials and more variables need to be introduced to see if his method holds true in other situations.

AFPEA has requested to work more closely with Dr. Burgess to develop this study and offer any assistance they can.

Industry POC: Dr. Gary Burgess
Government POC: Mr. Edward P. Moravec (See Appendix B)

2.3.3 Compressive Creep Study

2.3.3.1 Scope. AFPEA is in the process of developing test methods for generating high temperature compressive creep data for polyethylene and equivalent materials.

2.3.3.2 Test Methods. Creep testing is accordance with PPP-C-1752D except that the test period was shortened from 42 to 14 days to allow generation of information on more materials more quickly. Since creep rates of most materials tend to level off within one to two weeks and significant amounts of creep usually do not occur after this time, reducing the test period should still provide accurate data. Materials with creep rates that do not level off will be tested for a longer period.

2.3.3.3 Future Efforts. Data will be developed for polyurethane materials after completion of current testing.

POC: Ms. Susan J. Evans (See Appendix B)

2.3.4 Low Temperature Dynamic Cushioning Study.

2.3.4.1 Scope. AFPEA is working to develop low temperature dynamic cushioning data because of the interest expressed in such data by container designers at Picatinny, NWSF PHST and Eglin AFB. The data is being developed primarily for polyethylene and equivalent materials.

2.3.4.2 Test Methods. Cushions are first conditioned in a chamber to -20°F. The cushions to be tested at one static stress are then placed in a portable freezer unit placed next to the mounted cushion tester. Cushions are then removed from, tested and quickly replaced in the freezer. This minimizes any change in cushion temperature. The freezer unit is capable of conditioning samples to as low as -80°F or up to +140°F.

2.3.4.3 Future Efforts. After completion of all low temperature dynamic cushioning testing, high temperature testing may be performed, using the above method, at +140°F. AFPEA is also working to develop a method whereby a cushion tester can be permanently mounted in a chamber and the testing

process is automated. This would permit sample conditioning and testing to be completely carried out at the test temperature. Once this method is in place (approximately 2 years), AFPEA will be the only test facility in the country with such a setup.

POC: Ms. Susan J. Evans (See Appendix B)

2.3.5 Finite Element Analysis (FEA) and Cushioning Study

2.3.5.1 Scope and Future Efforts. ARDEC requested AFPEA to include FEA properties in the DAPC Cushioning Research. They would like cushioning data on modules of elasticity, poisson's ratio, and damping factors. Because of cushioning's non-linearity characteristics, AFPEA would test using different variables (size, thickness, etc.) to determine if consistent and reliable data is achievable. If our preliminary testing proves positive, then we will test on more materials. If the data can be used reliably, then cushioning performance would be included in the finite element analysis of containers. Container designers would be able to predict container responses much more closely using FEA programs.

POC: Mr. Edward P. Moravec (See Appendix B)

3.0 Conclusions

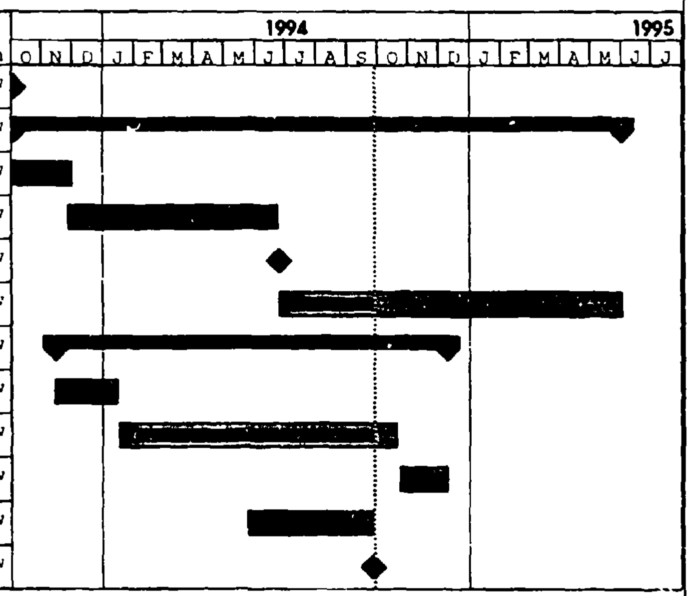
The sub-projects are varied, but they all relate to Cushioning Research. Some of the projects provide data and tools to use now. Cushion Curve Testing, Cushion Design Program, Isobutane Studies, Compressive Creep Testing, and Extreme Temperature testing can be used now to aid container designers. The Shortened Dynamic Cushion Testing and the Finite Element Analysis testing could prove to be leaps in technology if they are successful.

Studying one topic has lead to many new avenues to explore. This project started out with looking at Cushion Curve Testing and has expanded into many other forms of cushioning research.

APPENDIX A
SCHEDULE

DAPC ANTI-STATIC CUSHIONING
CAROLINE J. BUCKEY
93-P-110

ID	Name	Duration
1	FUNDING RECEIVED	0w
2	CUSHION CURVE TESTING	86.8w
3	DEVELOP SOW	8.6w
4	TECH REP BEFORE AWARI	30w
5	CONTRACT AWARD	0w
6	TECH REP AFTER AWARD	48.8w
7	UPDATE CUSH COMP PGM	56w
8	PREPARE SOW	9w
9	TECH REP DURING DEV	39.8w
10	DISTRIBUTE TO USERS	7w
11	GENERATE REPORT	17.8w
12	PRESENT REPORT	0w



93-P-110
26 Sep 94

Critical — Noncritical — Progress — Milestone — Summary — Rolled Up

APPENDIX B
Points of Contact

Ms. Caroline J. Buckey
Mechanical Engineer, AFPEA
HQ AFMC/LGTPM
5215 Thurlow Street
Wright-Patterson AFB OH 45433-5540
DSN 787-4519 or Comm (513) 257-4519

Ms. Susan J. Misra
Materials Engineer, AFPEA
HQ AFMC/LGTPM
5215 Thurlow Street
Wright-Patterson AFB OH 45433-5540
DSN 787-4519 or Comm (513) 257-4519

Mr. Larry Wood
Supervisor, Materials Engineering
AFPEA
HQ AFMC/LGTPM
5215 Thurlow Street
Wright-Patterson AFB OH 45433-5540
DSN 787-4519 or Comm (513) 257-4519

Mr. Steven C. Gerken, Program Manager
Engineering/Methods Lab
AGMC/MAEL
813 Irving-Wick Dr. W
Newark AFB OH 43057-0005
DSN 346-7383 or Comm (614) 522-7383

Ms. Ruth M. Doherty
Code R920
NSWC White Oak
10901 New Hampshire MD 20903-5640
DSN: 290-1180 Comm (301) 394-1180

Ms. Susan J. Evans
Materials Engineer, AFPEA
HQ AFMC/LGTPM
5215 Thurlow Street
Wright-Patterson AFB OH 45433-5540
DSN 787-4519 or Comm (513) 257-4519

Lt. Darrel Thomas
Support Systems IPT, Air Superiority JSPO
ASC/YA
207 W D Avenue Suite 622
Eglin AFB FL 32542-6844
DSN: 872-8090 or Comm (904) 678-8090

Mr. Edward P. Moravec
Physicist, AFPEA
HQ AFMC/LGTPM
5215 Thurlow Street
Wright-Patterson AFB OH 45433-5540
DSN 787-4519 or Comm (513) 257-4519

Mr. Rich Striebich
University of Dayton Research Institute
KL102-0132
300 College Park
Dayton OH 45469-0132
Comm (513) 229-2846

Ms. Ellen Stewart and Lt. John Garver
WL/POSF
Aero Propulsion and Power Directorate
Room 212, bldg 490, Area B
Wright-Patterson AFB OH 45433
DSN 785-4027 or Comm (513) 255-4027

Mr. David E. Filsinger
Mechanical Engineer, AFPEA
HQ AFMC/LGTPM
5215 Thurlow Street
Wright-Patterson AFB OH 45433-5540
DSN 787-4519 or Comm (513) 257-4519

Dr. Gary Burgess
Professor
School of Packaging
Michigan State University
East Lansing MI 48824-1223

APPENDIX C
DISTRIBUTION LIST

DTIC/FDAC
CAMERON STATION
ALEXANDRIA VA 22304-6145
(2 COPIES)

HQ AFMC/LG
WRIGHT-PATTERSON AFB OH 45433-5999

HQ AFMC/LGT
WRIGHT-PATTERSON AFB OH 45433-5999

HQ USAF/LGTT
WASHINGTON DC 20330

HQ USAF/LGTP (LIBRARY)
WRIGHT-PATTERSON AFB OH 45433-5999
(10 COPIES)

ATTN: MR RICH STRIEBICH
UNIVERSITY OF DAYTON RESEARCH INSTITUTE
KL102-0132
300 COLLEGE PARK
DAYTON OH 45469-0132

ATTN: STEVEN GERKEN
ENGINEERING/METHODS LAB
AGMC/MAEL
813 IRVING-WICK DR WEST
NEWARK AFB OH 43057-0005

ATTN MR AL GALONSKI
AMCPM-AL
US ARMY ARDEC
PICATINNY NJ 07806-5000

ATTN: MR EUGENE FARRELL
SMCAR-AEP
US ARMY ARDEC
PICATINNY NJ 07806-5000

ATTN: MR JIM RAEVIS
CODE 5022
NAVAL PHST CENTER
NAVAL WEAPONS STATION EARLE
COLTS NECK NJ 07722-5000

ATTN: MR GALE GROH
CODE 4045
NAVAL SURFACE WARFARE CENTER
CRANE IN 47522

ATTN: LT DARREL THOMAS
SUPPORT SYSTEMS IPT, AIR SUPERIORITY JSPO
ASC/YA
207 W D AVENUE SUITE 622
EGLIN AFB FL 32542-6844

DR GARY BURGESS
PROFESSOR
SCHOOL OF PACKAGING
MICHIGAN STATE UNIVERSITY
EAST LANSING MI 48824-1223

OVERTON PARRENT
NAVAL SURFACE WARFARE CENTER
DAHLGREN DIV
WHITE OAK DETACHEMNT CODE R95
10901 NEW HANPSHIRE AVENUE
SILVER SPRING MD 20903-5640

MS DORIS HEIDENREICH
ASC/ALXS
WRIGHT-PATTERSON AFB OH 45433

ATTN: LEE LIPSCOMB
ASC/YHC
102 WEST D AVENUE
SUITE 168
EGLIN AFB FL 32542-6807

ATTN: CHARLIE WEILL
GSA/FSS
COMMODITIES CENTER
ENGINEERING DIVISION
26 FEDERAL PLAZA
NEW YORK NY 10278

ATTN: JOHN LOCHNER
OO-ALC/LIWDT
6034 DOGWOOD
HILL AFB UT 84056-8516

ATTN: DR MICHAEL MADDEN
COMMANDFR, NAVAL ORDINANCE CENTER
FARRAGUT HALL
BUILDING D-323, CODE N7
23 STRAUSS AVENUE
INDIANHEAD MD 20640-5555

ATTN: MS RUTH DOHERTY
CODE R920
NSWC WHITE OAK
10901 NEW HAMPSHIRE MD 20903-5640

MS ELLEN STEWART AND LT JOHN GLOVER
WL/POSF
AERO PROPULSION AND POWER DIRECTORATE
ROOM 212, BLDG 490, AREA B
WRIGHT-PATTERSON AFB OH 45433

ATTN: J YANNELO (CODE EPP-A)
NAVAL AVIATION SUPPLY OFFICE
700 ROBBINS AVENUE
PHILADELPHIA PA 19111-5098

ATTN: FRANK SIECHRIST
CODE 0541
NAVY SHIPS PARTS CONTROL CENTER
PO BOX 2020
MECHANICSBURG PA 17055-0788

COMMANDING OFFICER
ATTN: F MAGNIFICO (SESD CODE 9321)
NAVAL AIR ENGINEERING CENTER
LAKEHURST NJ 08733-5100

COMMANDER
ATTN: G DAVIS
NAVAL SUPPLY SYTEMS COMMAND
WASHINGTON DC 20376-5000

ASC/POSF
WRIGHT-PATTERSON AFB OH 45433

ATTN: MR JOE MALONEY
DEFENSE LOGISTICS AGENCY
HQ DLA/MMDOS
CAMERON STATION
ALEXANDRIA VA 22304-6100

AMARC/DST
DAVIS MONATHON AFB AZ 85707-5000

MR JIM STATON
HQ AFMC/SEO
WRIGHT-PATTERSON AFB OH 45433

SGT MIKE ALCORN
HQ AFMC/XRWC
WRIGHT-PATTERSON AFB OH 45433

ATTN: MR MIKE BARNANSKY
US AMC PACKAGING STORAGE AND
CONTAINERIZATION CENTER
SDS/TO-TE-E
11 MIDWAY RAOD
TOBYHANNA PA 18466-5097

ATTN: MR LARRY FRANKS
DEAN
SCHOOL OF MILITARY PACKAGING TECHNOLOGY
ATSZ-MP
ABERDEEN PROVING GROUND MD 21005-5001

654 ABW/LGTPL
7701 2ND ST., SUITE 102
TINKER AFB OK 73145

651 ABG/LGTP
BLDG 1572, DOOR 1B
401 WILSON BLVD
KELLY AFB TX 78241

652 ABW/LGT
1961 IDZOREK ST, BLDG 783-A
MCLELLAN AFB CA 95652-1620

653 ABW/LGTP
455 BYRON ST.,BLDG 380
ROBINS AFB GA 31098-5999

649 ABG/LGTPD
5851 F AVE BLDG 89
HILL AFB UT 84056-5713